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Improved Diagnosis of Dental Caries Using Expert System

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ABSTRACT

There is no doubt that computing and its associated technologies have also transformed the medical domain with introduction of tools that help in medical diagnosis and prognosis of diseases. The field of medical dentistry has received a disturbing publicity in recent times as there are cases of dental problems in Nigeria which has put a burden on the limited number of dentists we have in the country. Studies have shown that many general hospitals in Delta state and in Nigeria do not have dentist that are primarily stationed on duty in the hospital and where there are one or two, the pressure on them in terms of service is enormous which ultimately leads to poor service delivery and eventual progression of dental problems such as caries to more complicated medical posture before they actually meet an expert. This consequently results in over working conditions for the dentists in attending to patients. The Expert system for diagnosis of dental caries gives real time result, fast without or with minimal error and is hoped to be integrated to the health-care system to enable general medical practitioners attend to some dental cases that are not so complicated and even complement the dental expert in diagnosis and management of caries disease.

1.0 INTRODUCTION

Technology has transformed the health-care industry, revolutionizing the way medical professionals diagnose, treat, and manage patient care. Technology breakthroughs have improved healthcare in many ways, from telemedicine and artificial intelligence to electronic health records. However, along with these advancements come various challenges. Expert systems for illness detection are interactive systems that let decision-makers use databases and models on a computer to solve unstructured problems. An expert system is a computer system that simulates the ability to make decisions of a human expert. An Expert system for disease diagnosis consists of problem-solving technology containing people, knowledge, software, and hardware to facilitate improved decision-making. This expert system for illness detection combines the use of group decision support systems (GDSSs) with numerous decision makers, as well as the integration and application of decision rules and weights from domain-specific experts. Expert systems are widely used in hospitality management as management information systems (MISs) to assist hospitality managers in making business decisions, or as travel recommendation systems to assist customers in making decisions about lodging and/or travel. Expert systems have been effectively implemented for yield management systems, agent counseling, budget allocation issues, and site selection analysis. While Expert system helps hospitality managers to make decisions, they do not replace managerial judgment. An ideal Expert system allows a manager to combine his or her experience and intuition with the consistent objectivity of a computer based model. An Expert system is the set of problem solving technology containing people, knowledge, software and hardware successfully wired into the management process to facilitate improved decision making by managers.

Analytical models are often used by expert systems to forecast, simulate, or optimize tasks. These are made with a general programming language or with a standard statistical or mathematical software package. Information technology advances in recent years have made software tools available to integrate heuristic data manipulation (expert systems) with inferential and deductive reasoning. Technologies such as neuro-computing and evolutionary programming have also shown promise in rapidly changing situations without expert skills. An expert system is a software system that is a conventional application and/or subfield of artificial intelligence that aims to replicate the performance of one or more human experts, usually in a particular problem domain.

Dentistry is the study, diagnosis, treatment, and prevention of illnesses, disorders, and ailments pertaining to the teeth, including the maxillofacial area, oral cavity, and related tissues, as well as how these affect the body as a whole. Most people agree that having dental health is essential for general well-being. Dentists are medical professionals who work in dentistry. Oral health treatments are assisted by the dentist's support staff, which consists of dental therapists, dental assistants, dental hygienists, and dental technicians.

The Medical Decision-Support System is a computer application meant to assist healthcare providers in making clinical decisions. The system uses medical data and knowledge domains to diagnose patients' problems and suggest appropriate courses of action for individual patients. Patient-Centered Health Information Systems is a patient centered medical information system developed to assist in monitoring, managing and interpreting patient's medical history [11]. In addition, the system provides assistance to patients and medical practitioners. The system serves to improve the quality of medical decision-making, increases patient compliance and minimizes medical errors. The advancement in computer technology and communication encourages health-care providers to provide health-care over the Internet or telemedicine [9]. According to Rusovick and Warner, telemedicine is any medical procedure carried out via the Internet while utilizing more specialist medical diagnostic tools in addition to real-time video teleconferencing technology. Broadly speaking, telemedicine refers to the utilization of computer and communications technologies to enhance the provision of medical treatment. Telemedicine can lower costs, raise the quality of healthcare, and facilitate better access to care. Both patients and physicians save money and time with this method.

Malak suggested utilizing artificial intelligence and the CLIPS (C Language Integrated Production System) framework to create an expert system for migraine diagnosis [5]. A strong inference engine is utilized by the rule-based programming language CLIPS to create expert systems. The authors hope that by implementing CLIPS, they would be able to provide a reliable and effective tool that will help medical practitioners diagnose migraines correctly. A fuzzy expert system was created by Fatemeh [3] for the diagnosis and management of musculoskeletal problems affecting the elbow and shoulder. To collect information about symptoms and therapies, the fuzzy Delphi technique is employed. Through knowledge acquisition, an expert system was created. Oladele develop a joint neuro-fuzzy malaria diagnosis system in the healthcare field [6]. The coactive neuro-fuzzy specialist system can be used to help in the diagnosis of malaria. The machine is an interactive interface that forecasts the severity of malaria in a person. Okpako and Asagba design a framework for the diagnosis of confusable diseases using neutrosphic based neural network [7]. Okpako et al. developed a neutrosophic based decision support system for the diagnosis of liver disease [8]. Fuzzy logic was applied to determine the degree of severity of tropical diseases.

Djam, and Kimbi, designed and implemented a fuzzy expert system for the management of hypertension [1]. In another study on a decision support system for tuberculosis diagnosis also reported in a decision support system based on fuzzy logic was used in the diagnosis of tuberculosis [1]. This hybrid system of the expert system is not adaptive in nature. Hence, it can only serve for cases that have been predefined in the knowledge base. This study seeks to design a medical expert system for dental caries diagnosis to simulate medical dentist skills in diagnosis and prescription of treatments of Dental caries and can be used to complement or provide the same service in the absence of the Dental experts. The proposed system used object analysis and design methodology while it was implemented using Visual basic programming. A typical architecture of an expert system is shown in Fig. 1

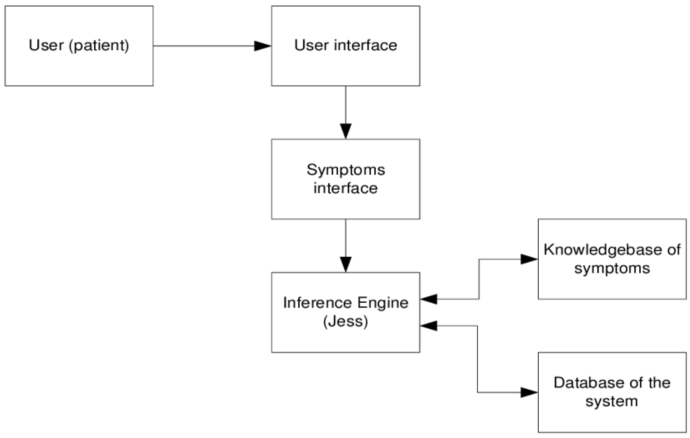

Figure 1: Architecture of a Typical Expert Eystem
(Source: Fatumo *et al*, 2013)

2.0 KNOWLEDGE ACQUISITION AND REPRESENTATION IN EXPERT SYSTEM

Knowledge acquisition is a crucial step in training a successful healthcare project. It involves gathering relevant information from domain experts, medical literature, and data sources to build a comprehensive knowledge base. while, Knowledge representation is the field of artificial intelligence dedicated to representing information about the world in a form that a computer system can utilize to solve complex tasks such as diagnosing a medical condition or having a dialog in a natural language. In order to construct formalism that will make complex systems easier to design and build, knowledge representation includes studies from psychology about how humans solve issues and represent knowledge. Psychological research on problem solving and knowledge expression is integrated with knowledge representation to produce a formalism that will make the design and development of complicated systems easier. Moreover, logic's discoveries are applied to knowledge representation and reasoning to automate a variety of reasoning processes, including the application of rules and set relations. Ontologies, frames, rules, systems architecture, and semantic nets are a few instances of knowledge representation formalism. Theorem proffers, classifiers, and inference engines are a few examples of automated reasoning engines. Our knowledge-based system represents the issues with teeth and gums using the SL5 Object language. The patient has the ability to answer numerous questions outlined in the program, which in turn gives them control over the quality of their therapy and the state of their illness.

The field of computational knowledge representation focuses on the symbolic representation and automated manipulation of knowledge. Nearly all of the aforementioned hypotheses developed in tandem with computer science. Computer science draws inspiration from the human brain to create computational systems, but it also utilizes artificial models to learn more about the biological underpinnings of knowledge representation. Rather than serving as a model of cognition, computational knowledge representation is mostly employed as an extension of database technology, allowing access to larger information repositories. General guidelines and models are not required in these situations.Growing storage capacity makes it possible to build basic knowledge bases with all the details. Sentential knowledge, or information stored in the form of sentences akin to propositions and program code, is how the data is kept. Instead than serving as evidence for a model of cognitive activity, knowledge is viewed as a storehouse of valuable information. More recently, larger available memory sizes have allowed for the usage of "compute-intensive" representations, which instead of declaring broad rules, merely list all the specific facts. They appear to give up on any pretense of psychological plausibility, but they permit the application of statistical methods like Markov simulation. Many other subjects that are related to information processing, such as logic, linguistics, reasoning, and the philosophical underpinnings of these fields, are tied to knowledge representation. Specifically, it is one of the key themes of AI since it addresses the encoding, storing, and application of information for computational models of cognition.

A quality knowledge representation system needs to have the following features.

1. Representational Accuracy: The KR system ought to be able to accurately represent every type of necessary information.

2. Inferential Adequacy: The KR system must be able to work with representational structures in order to generate new knowledge that correlates with the structure that already exists.

3. Inferential Efficiency: The capacity to store relevant guides and use them to steer the inferential knowledge mechanism in the most advantageous directions.

4. Acquisitional Efficiency: The capacity to quickly pick up new information through automated means.

2.1 MATERIAL AND METHOD

2.1.1 Analysis of the Existing System

Proper medical care for our dental health is a major concern in dentistry and it therefore necessary to have systems that can assist in dental care with such a comparative accuracy and performance to a human expert dentist. Though there has been considerable revolution in the use and application of computing technologies in medicine yet its use in dental care is limited. A detailed review and analysis of the existing manual system was done to ascertain areas to improve on. The following were reviewed:

i. The methods used in the existing system in knowledge construction
ii. Inference mechanism in handling uncertainties not precise
iii. Convenience and availability of service

In Nigeria, research has revealed that before receiving treatment, each patient must go through the manual procedure, which requires speaking with the on-call doctors directly. Each patient in this system has to deal with the anxiety of having to meet with the receptionists in order to obtain their card via a registered index number. The patient's card will then be manually traced by the receptionists using the index number before being taken to the doctor's desk. In this technique, the dentist determines the patient's illness by analyzing the patient's symptoms using their medical expertise and experience. The dentist may need to perform a practical examination in certain situations.

2.1.2 Expert System For Diagnosis on Dental Caries Diseases

When a patient visits a doctor and presents a collection of complaints, a medical diagnosis of Dental Caries disorders is initiated (symptoms). In circumstances when the patient's symptoms are severe, the doctor may next ask for more information from the patient or from those in the patient's immediate vicinity. Information gathered includes the patient's living situation, past health status, and other medical issues. Prior to receiving medical care, the patient is usually given a physical examination, and in most situations, a medical observation and/or test(s) are performed. The doctor creates a list of disorders that could be the cause of the patient's symptoms based on the symptoms the patient has presented. This helps to limit down the possibilities of the sickness that matches to the apparent symptoms. These are usually ranked in the order (Low, Moderate and high). The physician then conducts a physical examination of the studies his or her medical records and ask further questions, as he goes in an effort to rule out as many of the potentials. A typical data set that contains some symptoms is presented in the Table below. This shows the degree of intensity of the symptoms.

Table 1: Degree of intensity of symptoms (*Source: Clinical findings)*

RESULT	Tooth diseases	Might be Tooth diseases	Not Tooth diseases
Loss of sensation	0.60	0.30	0.10
Pain in chewing	0.30	0.55	0.15
Swelling gum	0.80	0.10	0.10
Muscle weakness	0.68	0.15	0.17
High foot ache	0.32	0.60	0.08
Weakness of joint	0.59	0.29	0.12
Severe toothache	0.20	0.15	0.65
Severe pain in the gum	0.18	0.70	0.12
Hole in the surface of the tooth	0.20	0.26	0.54
Nerves damage	0.20	0.26	0.54

2.1.3 Limitation of the Existing System

The existing system has some limitation which is affecting its performance in the 21st century of dentistry and service delivery. The existing manual system comprises of running a clinical test manually. The diagnoses are done with specimen or samples collected from the suspected patient and series of test is run to confirm if it is positive or negative. In the existing system, series of samples are collected even the patient tissue and images are collected for the test. Therefore, the existing system has many disadvantages such as time consuming, inaccurate result and mismatching of samples.

2.2 The Proposed System

The proposed system, expert system is design to tackle the problems of the existing system and to make work easy for the laboratory scientist. the system operates with a simple algorithm where by the patient will specify or select the major symptoms of unusual feelings he or she is observing in recent time, thus as the patient make his or her selection the selected option will generate the result instantly with a very short time the algorithm or technique used to determine the result from the request is called the logic technique or fuzzy logic. The architecture of the proposed system is adapted from Brainkart, 2022 as shown in Figure 2.

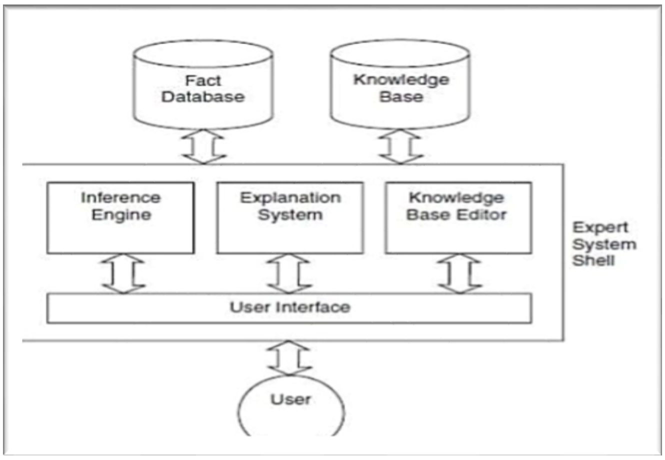

Figure 2: Architecture of the Proposed System (Source: Adapted from Brainkart, 2022)

2.3 Brief Description of the Material and Components of the Proposed System

1. User Interface Design

As displayed in Figure 3, the expert system that is being offered is able to diagnose dental caries problems at various phases of a person's life. It begins by asking the patient a series of questions depending on their pain symptoms. The patient receives a clear understanding of the illness and the cause of their pain from this expert system. Finally, the suggested expert system offers treatment recommendations for the Dental Caries Disease list of ailments that may be causing the patient's problems. The proposed Expert System for Dental caries Diagnosis was implemented using, a Developer IDE called Visual Studio in C# programming languages were used for designing and implementing the proposed expert system, This Expert System allows the user to display a list of questions and analyzed it based on the user's answers, as well as present the appropriate diagnosis and give treatment recommendations according to the user's answers. Fig. 4. shows the main screen of the expert System, the symptoms, diagnosis and recommendation about the disease.

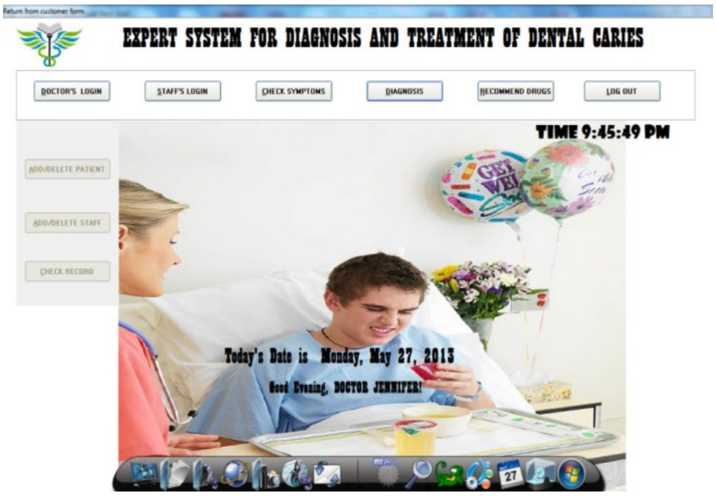

Figure 3: Main menu

Users of this form can choose from a list of options the kind of medical problem they would like to diagnose. The user will still have to fill out a form with questions the expert will pose based on the medical case's history and symptoms. Either "Yes" or "No" is the response. Once more, the form offers an option for the user to get more information about a specific illness. To help users, particularly those who are blind or visually handicapped, the interface also has auditory capabilities. The question is read aloud via the audio feature.

2. Knowledge base

The structured collection of information regarding the system domain is described in the knowledge base. The database that holds the fundamental parameters from the back-end design makes up the knowledge base. The breadth of data acquired on the clinical signs of dental caries served as a major source of inspiration for this expert system's knowledge base. In hospitals, the patient-to-dentist ratio and, eventually, consultation time have been reduced thanks to the application of this strategy and the knowledge it contains, which is kept as facts and regulations. In addition, this expert system helps collect patient medical data through the app for use in dental caries, so that dental consultations are accessible without physical barriers. The design of the database was done using Microsoft Access version 7.0. During the design, the following consideration was done. The total number of tables that would be required to store all the tabular data. The table again is designed considering the data items to be stored, with respect to their field names.

Figure 4: Patient Diagnostic page

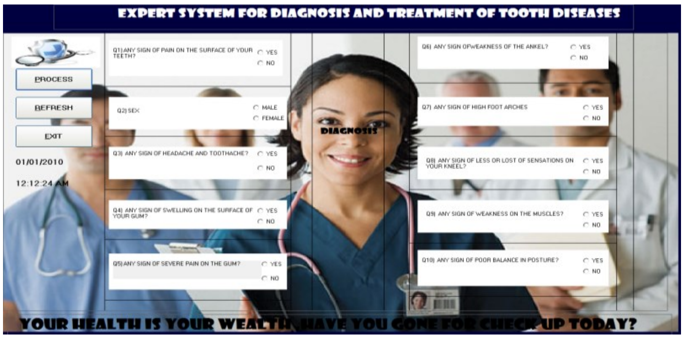

Figure 5: Patient Investigation page

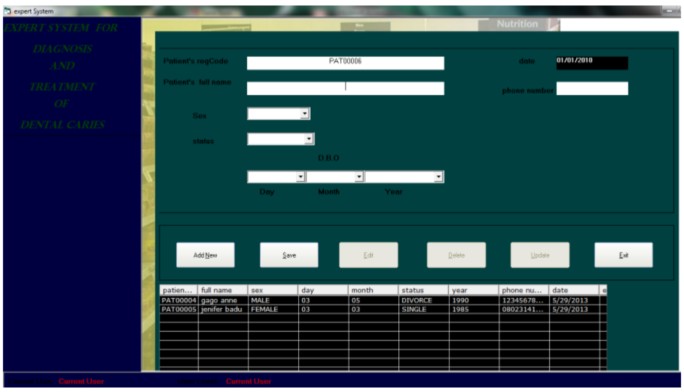

Fig 6: Patients Database

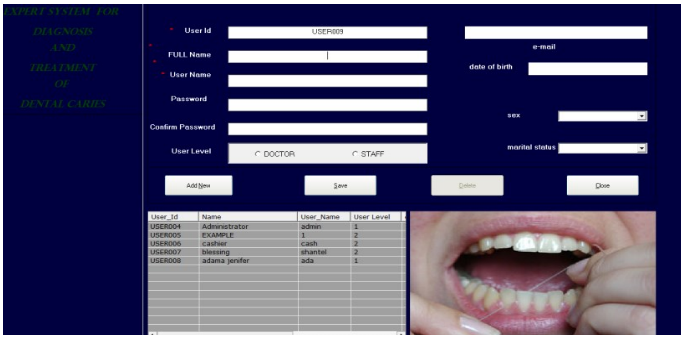

Fig 7: Doctors Database

when you begin the diagnosis process on this form, each question to which you select "yes" will be assigned a score based on how well the symptom fits the diagnosis. upon completion of each diagnosis, the percentage of infection will be displayed. in addition, the expert system analyzes the situation and advises you to validate the test in a laboratory if necessary, indicating whether or not the condition is severe. there is a database connection on this form as well. the database content will be obtained as you continue to answer the expert's question.

3.1 Fuzzy Logic and Fuzzification of Knowledge in the Inference Engine

Fuzzy Sets

A set with sharp, precise bounds is referred to as classical. Take a set of even numbers, for instance. {2, 4, 6, 8, 10} is A. This is a distinct and obvious border. As a result, an odd number is not included in the collection. A fuzzy set, as opposed to a classical set, lacks a sharp or distinct boundary. Partial membership is also permitted. That is, membership functions that produce fuzzy sets characterize the seamless transition from "belonging to a set" to "not belonging to a set." The adaptability of the modeling of widely used language phrases like "the body is warm" or "the temperature is high.".Because parameter values are frequently ambiguous (fuzzy) and imprecise, fuzzy logic is used in this model to analyze the data. The knowledge base is made up of the database, which is made up of the previously mentioned fourteen fundamental factors. As a result, these parameters make up the knowledge base's fuzzy parameter. "P," which is defined as P= {P1, P2…, Pn}, where Pi denotes the jth parameter and n is the number of parameters (in this case, n=14), indicates the fuzzy set of parameters. L= {Low, Moderate, and High} is the collection of linguistic values that is represented as a linker scale.

Neural networks provide the structure for the parameters, which serves as a platform for the inference engine. The inference engine consists of reasoning algorithm driven by production rules. These production rules are evaluated by using the forward chaining approach of reasoning. The inference process is powered by fuzzy logic. The decision support engine's cognitive filter uses the inference engine's output report as input and applies objective rules to rank the person according to the presence or absence of dental diseases. To rank people according to the severity of their dental illness, the emotional filter uses the cognitive filter's output report as input and adds subjective study rules. A uniform set of symptoms for dental disorders is provided to the patient, who is supposed to select or pick from the list of symptoms fed into the system in order to diagnose the condition. We employed a straightforward binary encoding approach, where a symptom is denoted by 1 in the input vector when it exists and 0 otherwise (this is referred to as the symptom vector). Figure 8 illustrates the model's operational process. The network receives the set of symptoms. It is expected of the patient to select the symptom from the list that best describes their current condition. The patient has severe dental disease and needs to see a dentist right once if he exhibits five or more of the symptom. If it is approximately four of the symptoms he is having, he might be suffering from Tooth diseases and hence should see a physician right away, but if it is three or lesser of the symptoms, he may not be having Dental disease.

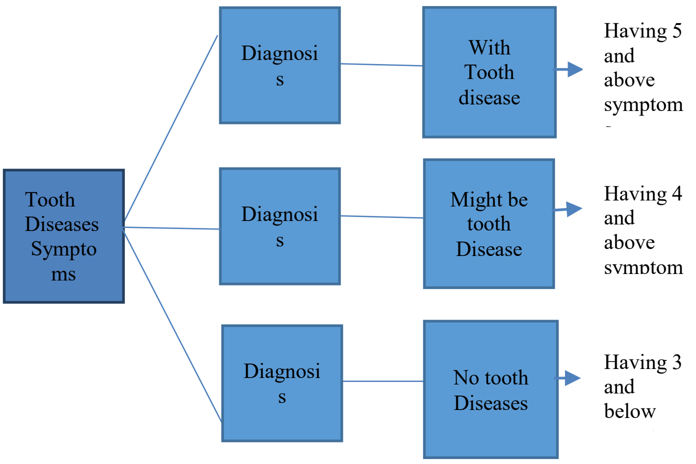

Figure 8: Procedural Operation of the fuzzy system for the diagnosis of Dental Disease

3.2 Fuzzy Sets and Functions of Membership

In the discourse universe of U, a fuzzy set A is a set of ordered pairs and is denoted by the formula

A = {x, µA(x) ? xϵU} (1)

Here, µA(x) is the membership function (MF) of x in A, signifying the degree to which x belongs to A. The membership degree µA(x) is assumed to have values between 0 and 1. In other words, each element of U is mapped by the membership function (MF) to a continuous membership value, also known as a membership grade, between 0 and 1. The instruments that translate the idea of fuzzy logic into algorithms are fuzzy sets. One way to conceptualize fuzzy sets is as a means of translating human cognitive processes to computer programs. Regardless of whether the set's elements are discrete or continuous, the membership function determines the degree of fuzziness in a fuzzy set. Typically, membership functions are shown graphically. Fuzzy rules also define fuzzy graphic definitions. Using a variety of shapes, including the triangular, trapezoidal, sigmoidal, and Gaussian membership functions, MF assigns a membership grade between 0 and 1 to each element of U.

For this reason,

µA(x)=1 If x is completely in …………………. (2)

A(x) is equal to zero Should x not be present in.… (3)

O<µA(x)<1. ……………………………………….. (4)

In the event that x is partially in. 4. The value of 1 in Equation 1 denotes absolute membership. Equation 2 indicates that the number 0 represents total non-membership. Partial membership is represented by the value in equation 3 that falls between 0 and 1. The suggested expert system was developed using the widely utilized triangular membership function.

3.3 Inference Engine / Decision Maker

To offer a response, the inference engine analyzes and interprets the data in the knowledge base. The inference engine compares information in the patient database with rules in the rule base to decide which rules apply based on the engine's chosen logic. The decision or dental recommendation through the use of this inference mechanism from the fuzzified knowledge base, thus inputted information is been made.

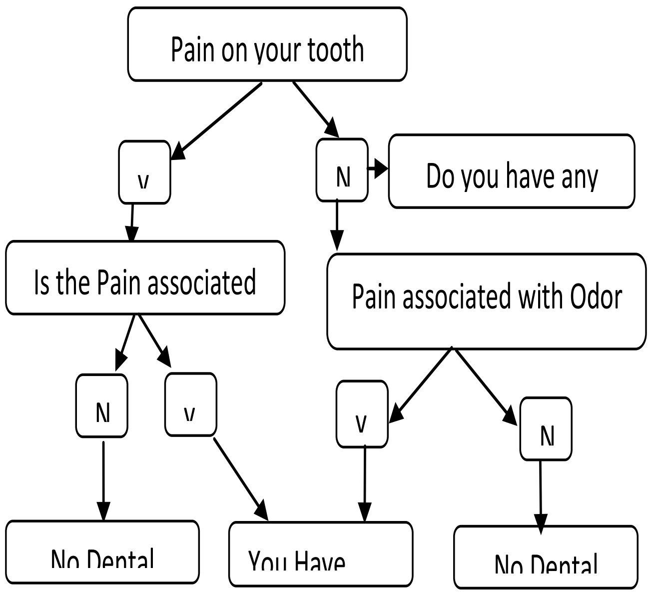

Figure 9: The Decision-Making Process and Interaction with Users With the Expert System.

4.0 RESULT AND DISCUSSION

Patients experiencing pain related to dental caries underwent an initial test. Every patient who used this professional technique for testing was pleased and at ease with it. The performance and efficacy of the expert system for diagnosing dental caries illnesses are evaluated using a variety of criteria. The two main assessment criteria that are frequently employed in diagnostic systems are specificity and sensitivity. The system's capacity to correctly identify patients with dental caries illnesses is measured by sensitivity, while its ability to accurately identify patients without dental caries diseases is measured by specificity. Positive predictive value (PPV), negative predictive value (NPV), and overall diagnosis accuracy are additional evaluation criteria. These metrics offer numerical insights into the system's functioning, making it possible to evaluate its diagnostic capabilities in-depth.

4.1 Accuracy of Diagnoses

One of the most important factors in assessing the expert system is diagnosis accuracy. The expert system is evaluated on datasets of patients with dental caries disease, and the diagnostic results are compared to the reference standard to ascertain the accuracy. The reference standard may be determined by clinical guidelines or by expert consensus. By comparing the total number of cases reviewed with the number of accurate diagnoses the expert system made, the diagnostic accuracy is determined. When an expert system has a high accuracy rate, it can accurately determine the dental caries disease stage, which helps medical practition ers make appropriate diagnoses. The research variable is summarized the Table 2 and3.

4.2 Comparison with Traditional Diagnosis Methods

To evaluate the benefits of the expert system, a comparison was made with conventional diagnosis techniques such lab testing and physical examinations. The efficiency and accuracy of this expert system for diagnosis of dental caries were significantly higher than those of conventional techniques. This expert system can provide real-time feedback quickly, whereas older approaches can be expensive and time-consuming. Time and resources are saved by the expert system's quick and precise diagnosis. In addition, the system demonstrated an increase in diagnostic accuracy and a greater accuracy rate when compared to conventional techniques. These results demonstrate the expert system's ability to supplement or perhaps completely replace some components of conventional diagnostic techniques, resulting in more accurate and efficient diagnosis of dental caries illnesses.
Using the specification as a guide, a usability research was conducted. A questionnaire was created and given to patients and physicians. Three elements comprised the survey questionnaire: background information, system efficiency, and user satisfaction. The four questions in each section on efficiency and user satisfaction are denoted by the letters Q1, Q2, Q3, and Q4. Only 10 of the 12 surveys that were sent out were collected, examined, and reported (see Table 3). A 5-point Likert scale, with **(1)** denoting severely disagree, **(2)** disagree, **(3)** undecided, **(4)** agree, and **(5)** strongly agree, was used to develop the questions .

Table 2: Result showing Effectiveness answer of user's response

EFFICIENCY				
	SURVEY QUESTIONS	AVERAGE	SD	VAR*(100)
Q1	The expert system saves time	4.10	0.57	32
Q2	With this expert system, i complete my task on time	4.00	0.47	22
Q3	It enable users to navigate the user interface on time when using the system	4.10	0.57	32
Q4	I didn't have to carry out too many task before completing my request	4.20	0.42	18
AVERAGE		4.10	0.51	0.26
USER'S SATISFACTION				
	SURVEY QUESTIONS	AVERAGE	SD	VAR
Q1	This expert system is easy to learn	4.00	0.67	0.44
Q2	This expert system user-friendly	4.40	0.52	0.27
Q3	Derived satisfied using the system	3.90	0.57	0.32
Q4	This expert system met my need	4.30	0.48	0.23
AVERAGE		4.15	0.56	0.32
AVERAGE RATING		4.08	0.54	0.30

User survey results N = 10.

S/N	Usability	Responses from Medical doctors	Responses from Users or patient	Total number of respondents	Total mean
1	Efficiency	4	6	10	**4.10**
2	User's Satisfaction	2	8	10	**4.15**
	MEAN RATING				**4.08**

Table 3: Descriptive Statistical Analysis Of Questionnaire

T Data **Background information**

- ✓ Would you support the use of computer diagnosis for Dental Caries in your hospital? (yes/no)6/4
- ✓ Do you need more computing skills/training/time to be able to use the system? (yes/no) 5/5

5.0 CONCLUSIONS

Expert systems for the diagnosis of Dental caries have been found to be very useful in our today's world driven by technology. It saves time and give real time feedback for urgent response to treatment and drug administration. It is designed to help patients to conduct their own diagnosis without contacting any dentist and also assist the dentist not to replace them. This means instead of a patient consulting the dentist, the patient can just access the system, test for diagnosis and can receive personal treatment through the expert system. When an expert's knowledge is retrieved and preserved, it can be utilized to take their place in the event of their death. Given that the medical area is composed of a small number of specialists, medical diagnosis will benefit more from the expert system. In an emergency, the expertise of such a specialist can be duplicated and applied. It is necessary to support the growth of expert systems. A hybrid expert system and artificial neural network (ANN) system is being implemented in an effort to improve this one.

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